CLAIMS

1. A method of fabricating a piezoelectric composite device, comprising steps for:

providing a first layer of electrically non-conductive film;

disposing a first electrically conductive lead over the first layer of electrically non-conductive film;

disposing a piezoelectric wafer over the first electrically conductive lead and the first layer of electrically non-conductive film;

disposing a second electrically conductive lead over the piezoelectric wafer;

disposing a second layer of electrically non-conductive film over the second electrically conductive lead and the wafer;

retaining the films, leads and the wafer in predetermined positions, wherein the layers of film, the electrically conductive leads, and the wafer form a laminate assembly; and

consolidating the laminate assembly into a highly flexible piezoelectric composite device, wherein the first and second layers of electrically non-conductive film each have a predetermined coefficient of thermal expansion that is substantially greater than the predetermined coefficient of thermal expansion of the piezoelectric wafer.

2. The method according to claim 1 wherein the step for retaining comprises:

providing a first layer of electrically non-conductive adhesive tape having at least one adhesive side;

thereafter, disposing the first layer of electrically non-conductive film over the at least one adhesive side of the film; and

disposing a second layer of electrically non-conductive adhesive tape having at least one adhesive side over the second electrically non-conductive film such that the at least one adhesive side of the second layer of electrically non-conductive tape contacts the second electrically non-conductive film.

3. The method according to claim 2 further comprising removing the first and second layers of electrically non-conductive tape after the step for consolidating.

4. The method according to claim 1 wherein the step for consolidating the laminate assembly comprises:

bagging the laminate assembly with a third electrically non-conductive material;

providing a pressure chamber;

inserting the bagged laminate assembly into the chamber;

controlling the chamber to provide a predetermined pressure at a predetermined temperature;

venting gasses within the bagged laminate assembly;

maintaining the predetermined pressure and temperature for a predetermined amount of time; and

controlling the chamber to release the vacuum and reduce the pressure and to reduce the temperature to ambient temperature.

5. The method according to claim 4 wherein the step of bagging comprises the steps of:

providing a substantially flat plate;

placing the laminate assembly on the plate; and

covering the laminate assembly with the third electrically non-conductive material and sealing the material to the periphery of the plate to form an airtight seal.

6. The method according to claim 5 wherein the step of bagging further comprises the step of forming an opening in the third electrically non-conductive material to allow venting of gasses.

7. The method according to claim 1 wherein the step for consolidating comprises vacuum sealing the laminate assembly.

8. The method according to claim 1 wherein each layer of electrically non-conductive film is a polyimide film.

9. The method according to claim 1 wherein each of the layers of tape and film has a width and wherein (i) the wafer has a first widthwise end and a second widthwise end, (ii) the width of first layer of film is less than the width of the first tape, (iii) the first electrically conductive lead contacts a portion of the wafer that is in proximity to the first widthwise end of the wafer, (iv) the second electrically conductive lead contacts a portion of the wafer that is in proximity to the second widthwise end of the wafer, and (v) the width of the second layer of electrically non-conductive tape is greater than the second layer of electrically non-conductive film.

10. The method according to claim 1 wherein each of the layers of tape and film has a length and wherein (i) the length of first layer of tape is greater than the length of the first layer of film, (ii) the length of the first layer of film is greater than the length of the first conductive lead, (iii) the length of the first layer of film is greater than the length of the wafer, (iv) the length of the second layer of film is greater than the length of the wafer, (v) the length of the second layer of film is greater than the second conductive lead, and (vi) the length of the second layer of tape is greater than the length of the second layer of film.

11. The method according to claim 1 wherein the wafer has a predetermined coefficient of thermal expansion and each of the electrically non-conductive films has a different predetermined coefficient of thermal expansion wherein none of the coefficients of thermal expansion of the films are the same as the predetermined coefficient of thermal expansion of the wafer.

12. The method according to claim 1 wherein the step of providing comprises the steps of:

providing a mold that has a substantially flat surface; and

thereafter, disposing a first layer of electrically non-conductive adhesive tape on the flat surface such that an adhesive side of the tape faces up.

13. A method of fabricating a piezoelectric composite device, comprising the steps for:

providing a substantially flat surface;

disposing a first layer of electrically non-conductive adhesive tape on the surface such that the adhesive side of the tape faces up, the layer of tape having a predetermined width;

disposing a first layer of electrically non-conductive film over the first layer of tape, the layer of film having a second predetermined width that is less than the first predetermined width, the layer of film having a first widthwise end and a second widthwise end;

disposing a first electrically conductive lead over the first layer of electrically non-conductive film, the lead contacting a portion of the film that is in proximity to the first widthwise end of the layer of film;

disposing a piezoelectric wafer over the first electrically conductive lead and the first layer of electrically non-conductive film, the wafer having a third predetermined width that is less than the second predetermined width;

disposing a second electrically conductive lead over the piezoelectric wafer, the second conductive lead being in contact with a portion of the wafer that is in proximity to the second widthwise end of the wafer;

disposing a second electrically non-conductive film over the second electrically conductive lead and the wafer, the second electrically non-conductive film having a fourth predetermined width that is generally the same as the second predetermined width;

disposing a second layer of electrically non-conductive adhesive tape over the second electrically non-conductive film such that the adhesive side of the tape contacts the second electrically non-conductive film, the second layer of tape having a fifth predetermined width that is generally the same as the first predetermined width;

wherein the layers of electrically non-conductive tape and film, the electrically conductive leads, and the wafer form a laminate assembly,

consolidating the laminate assembly; and

thereafter, removing the first and second layers of tape after the laminate assembly is consolidated.

14. The method according to claim 1 wherein the step for consolidating the laminate assembly comprises use of a hot press.

15. The method according to claim 14 wherein the step for consolidating the laminate assembly comprises:

cleaning the platens of the hot press and aligning the platens to be flat and substantially parallel;

covering the bottom platen of the hot press with a high temperature cloth;

placing the laminate assembly on the high temperature cloth;

covering the laminate assembly with a second piece of high temperature cloth;

covering the second piece of high temperature cloth with a rubber sheet;

heating the laminate assembly to a predetermined temperature that is above the glass transition temperature of the first and second layer of electrically non-conductive film and is below the Curie temperature of the piezoelectric wafer;

applying a pre-determined amount of pressure;

holding the pre-determined temperature and pressure for a pre-determined amount of time;

cooling the pressed assembly to ambient room temperature;

removing the applied, pre-determined pressure; and

removing the consolidated laminate assembly from the hot press.

16. The method according to claim 15 wherein the pre-determined temperature is 325° C.

17. The method according to claim 15 wherein the pre-determined amount of pressure is 300 psi.

18. A piezoelectric composite device made according to the method of claim 1.

19. A piezoelectric composite device made according to the method of claim 4.

20. A piezoelectric composite device made according to the method of claim 14.

21. A piezoelectric composite device made according to the method of claim 15.

22. An apparatus comprising:

a piezoelectric wafer having a first electroded surface and a second electroded side opposite to said first electroded surface;

a first electrically conductive ribbon lead positioned over and in electrical contact with the first electroded surface of the piezoelectric wafer;

a second electrically conductive ribbon lead positioned over and in electrical contact with the second electroded surface of the piezoelectric wafer; and

a layer of curable, electrically non-conductive material, the layer of material surrounding the piezoelectric wafer and the first and second electrically conductive ribbon leads, the layer of curable, electrically non-conductive material having a coefficient of thermal expansion that is substantially greater than the coefficient of thermal expansion of the piezoelectric wafer, the layer of curable, electrically non-conductive material compressing the piezoelectric wafer to such a degree that the piezoelectric wafer becomes highly flexible.

23. The apparatus according to claim 22 wherein the first electroded surface comprises a thin surface deposit of nickel.

24. The apparatus according to claim 22 wherein the second electroded surface comprises a thin surface deposit of nickel.

25. The apparatus according to claim 22 wherein the first electrically conductive lead is made of nickel.

26. The apparatus according to claim 22 wherein the second electrically conductive lead is made of nickel.

27. The apparatus according to claim 22 wherein the layer of curable, electrically non-conductive film is a thermoplastic polyimide.

28. The apparatus according to claim 22 wherein the piezoelectric wafer is made of lead zirconate titanate.

29. An apparatus comprising:

a piezoelectric wafer having a first electroded surface and a second electroded side opposite to said first electroded surface;

a first electrically-conductive ribbon lead positioned over and in electrical contact with the first electroded surface of the piezoelectric wafer;

a second electrically-conductive ribbon lead positioned over and in electrical contact with the second electroded surface of the piezoelectric wafer; and

a layer of curable, electrically non-conductive material, the layer of material surrounding the piezoelectric wafer and the first and second electrically conductive ribbon leads, the layer of curable, electrically non-conductive material having a coefficient of thermal expansion that is substantially greater than the coefficient of thermal expansion of the piezoelectric wafer, the layer of curable, electrically non-conductive material compressing the piezoelectric wafer to such a degree that the piezoelectric wafer becomes capable of being wrapped around a highly curved surface.

30. The apparatus according to claim 29 wherein the first electroded surface comprises a thin surface deposit of nickel.

31. The apparatus according to claim 29 wherein the second electroded surface comprises a thin surface deposit of nickel.

32. The apparatus according to claim 29 wherein the first electrically conductive lead is made of nickel.

33. The apparatus according to claim 29 wherein the second electrically conductive lead is made of nickel.

34. The apparatus according to claim 29 wherein the layer of curable, electrically non-conductive film is a thermoplastic polyimide.

35. The apparatus according to claim 29 wherein the piezoelectric wafer is made of lead zirconate titanate.

36. An apparatus comprising:

a piezoelectric wafer having a first electroded surface and a second electroded side opposite to said first electroded surface;

a first electrically-conductive ribbon lead positioned over and in electrical contact with the first electroded surface of the piezoelectric wafer;

a second electrically-conductive ribbon lead positioned over and in electrical contact with the second electroded surface of the piezoelectric wafer; and

a layer of curable, electrically non-conductive material, the layer of material surrounding the piezoelectric wafer and the first and second electrically conductive ribbon leads, the layer of curable, electrically non-conductive material having a coefficient of thermal expansion that is substantially greater than the coefficient of thermal expansion of the piezoelectric wafer, the layer of curable, electrically non-conductive material compressing the piezoelectric wafer to such a degree that the piezoelectric wafer is capable of being sharply bent.

37. The apparatus according to claim 37 wherein the first electroded surface comprises a thin surface deposit of nickel.

38. The apparatus according to claim 37 wherein the second electroded surface comprises a thin surface deposit of nickel.

39. The apparatus according to claim 37 wherein the first electrically conductive lead is made of nickel.

40. The apparatus according to claim 37 wherein the second electrically conductive lead is made of nickel.

41. The apparatus according to claim 37 wherein the layer of curable, electrically non-conductive film is a thermoplastic polyimide.

42. The apparatus according to claim 37 wherein the piezoelectric wafer is made of lead zirconate titanate.